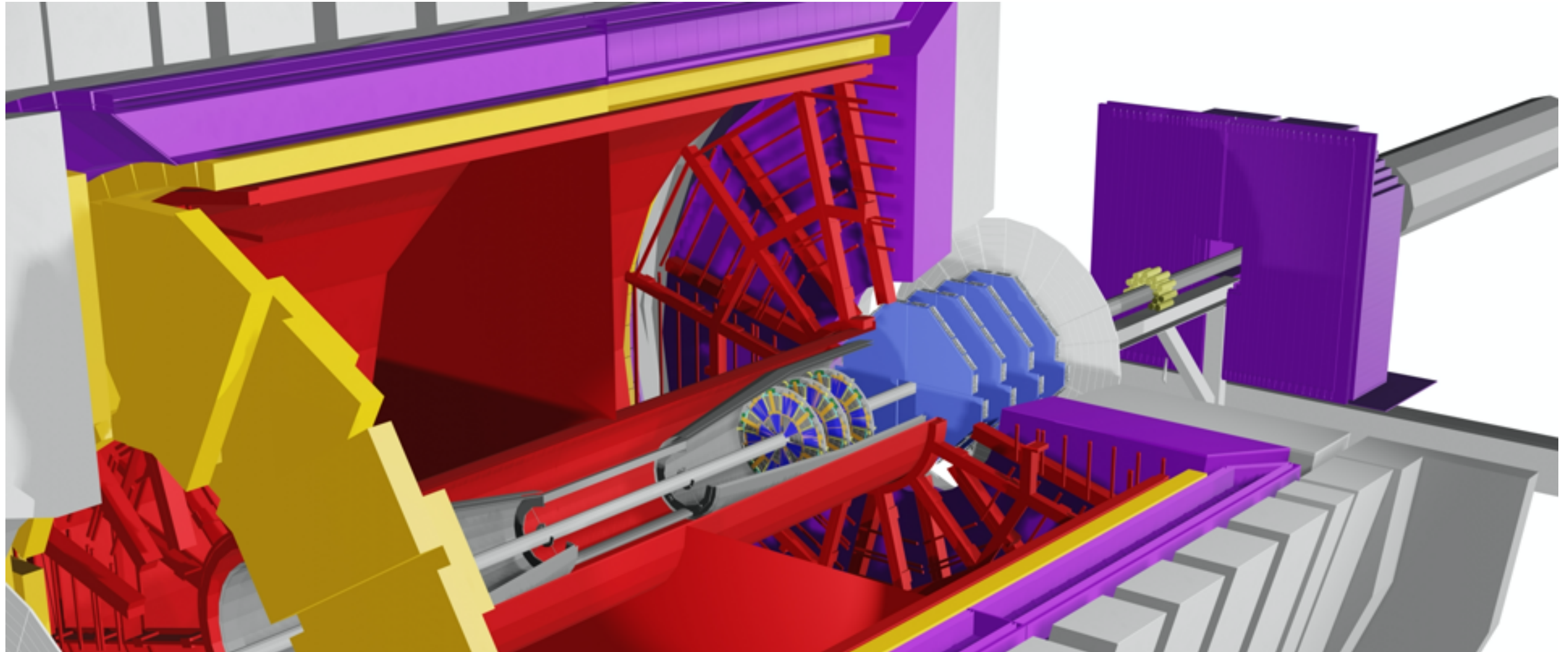


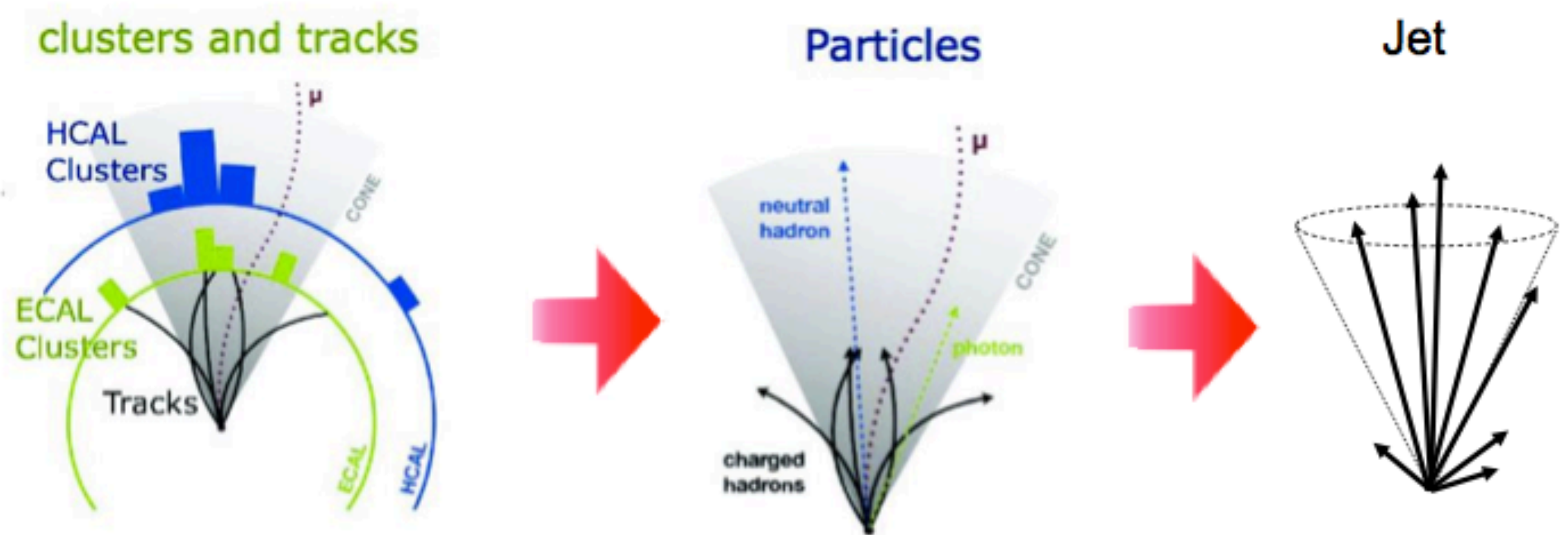
# Particle Flow for STAR-Forward



Raghav Kunnawalkam Elayavalli (Yale/BNL)  
STAR-Forward Software Meeting  
Feb 12th, 2021

# Particle Flow (PF)

30 second overview

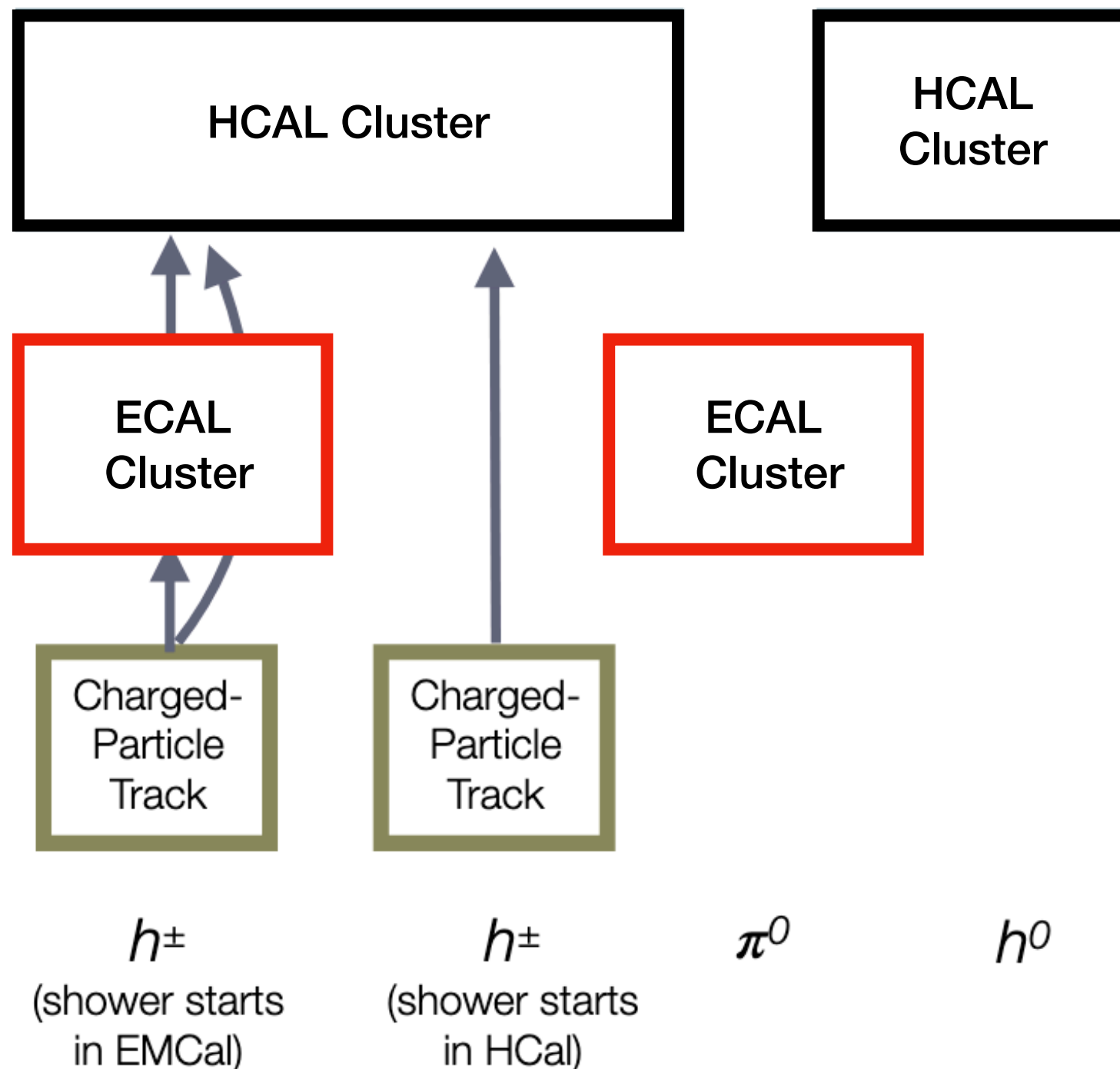


CMS, JINST 12 (2017) P10003

- Start with ch-tracks + ECAL cluster + HCAL cluster
- Ends with ch-hadron, ne-hadron, photon, lepton ( $e$ ,  $\mu$ )

# Particle Flow (PF)

## A bit longer overview



- Devil is in the details!
- Follow along the implementation as published in the CMS paper
- Match tracks in eta-phi w/ ECAL cluster and separately to HCAL cluster (contained within)
- many-to-one matching - a track can only match one ECAL/HCAL cluster, but a cluster can have multiple tracks matched to it (cluster is important vs single tower to include spread in energy deposition)
- Match ECAL cluster to HCAL cluster (same many-to-one as w/ tracks)

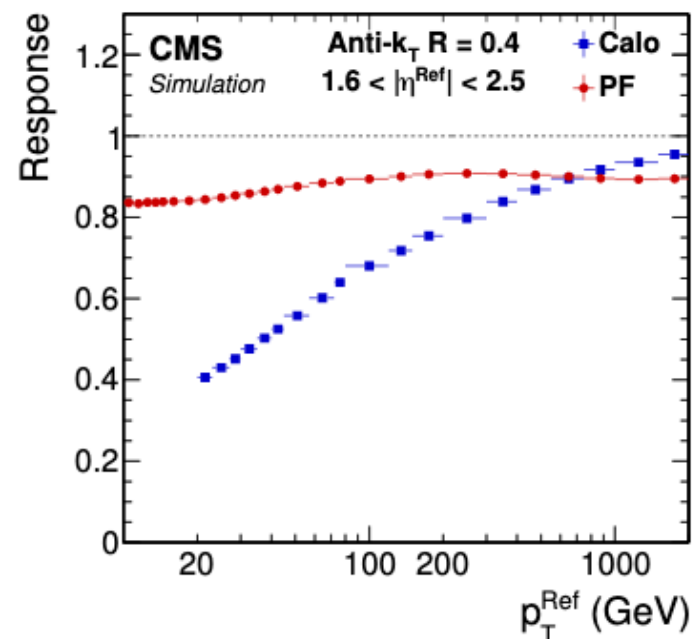
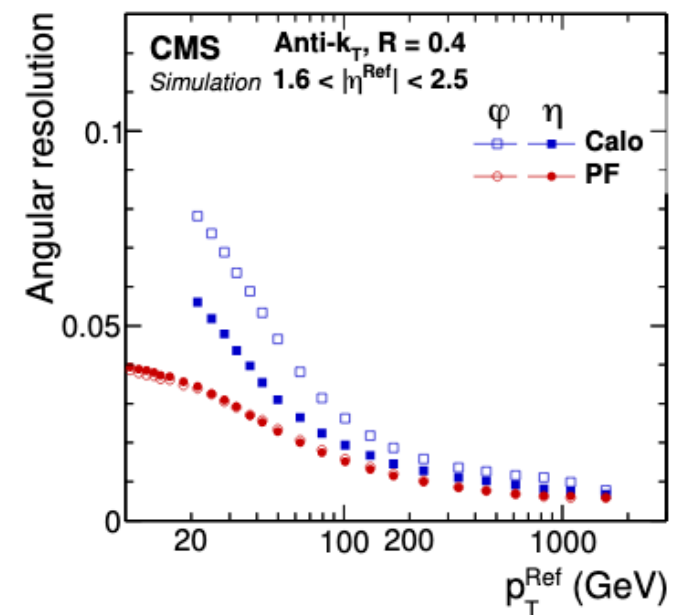
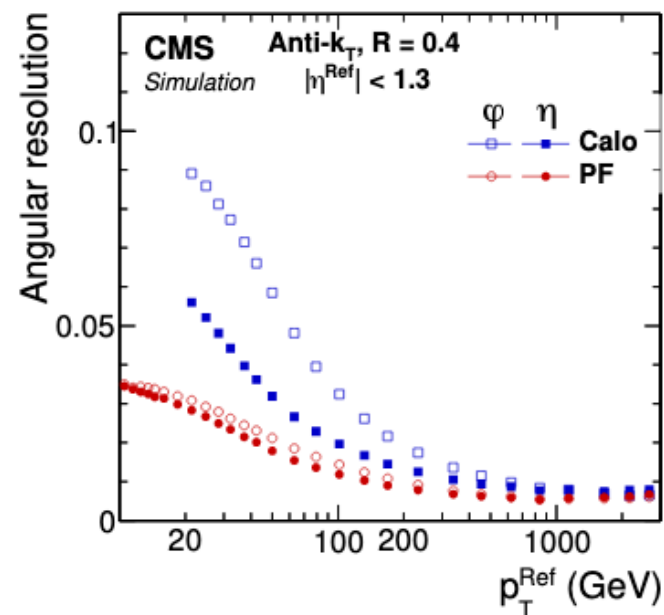
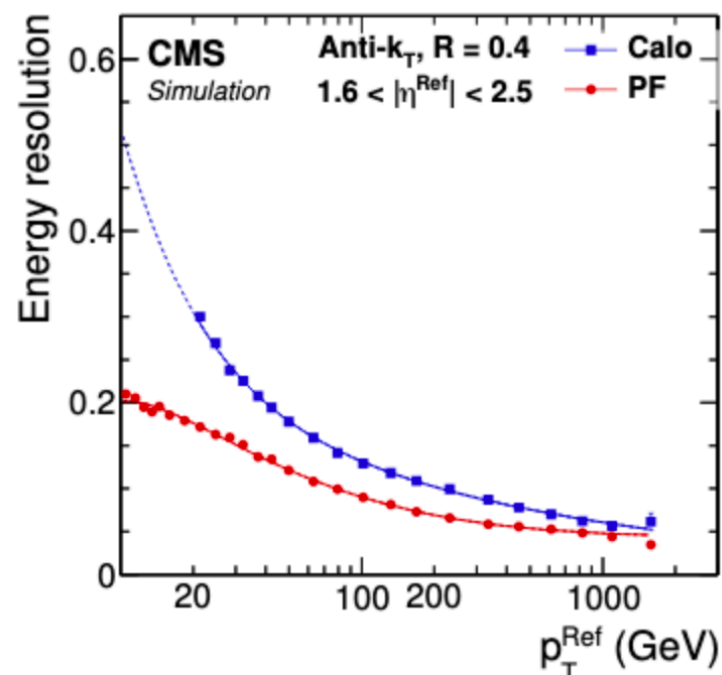
# Particle Flow (PF)

## Calibrations/Corrections

- Starting from HCAL clusters, sum total the matched track momenta - (similar to our hadronic correction or pT subtraction)
- From simulations (mainly, backed up by tests in data), we prepare a table of energy depositions from particles - mean and sigma
- Prepare separate collections - tracks matched with ECAL & HCAL (including the cases where ECAL and HCAL clusters are matched themselves), ECAL (or) HCAL clusters w/o tracks - taken as photons or neutral hadron clusters
- Compare  $\sum E$  with  $\langle E_{dep} \rangle + c\sigma_{E_{dep}}$  where c is a parameter depending on geant simulations - remove all tower clusters and turn the track into a PF candidate depending on ECAL/HCAL clusters present (can be ch-hadron or electron if no HCAL input)
- Similarly compare collections with only tracks and ECAL clusters or only tracks with no matched clusters
- Finally end with a collection of PF 4-vectors with an identifier of photon, electron (muon), charged hadron and neutral hadron

# Utility of PF

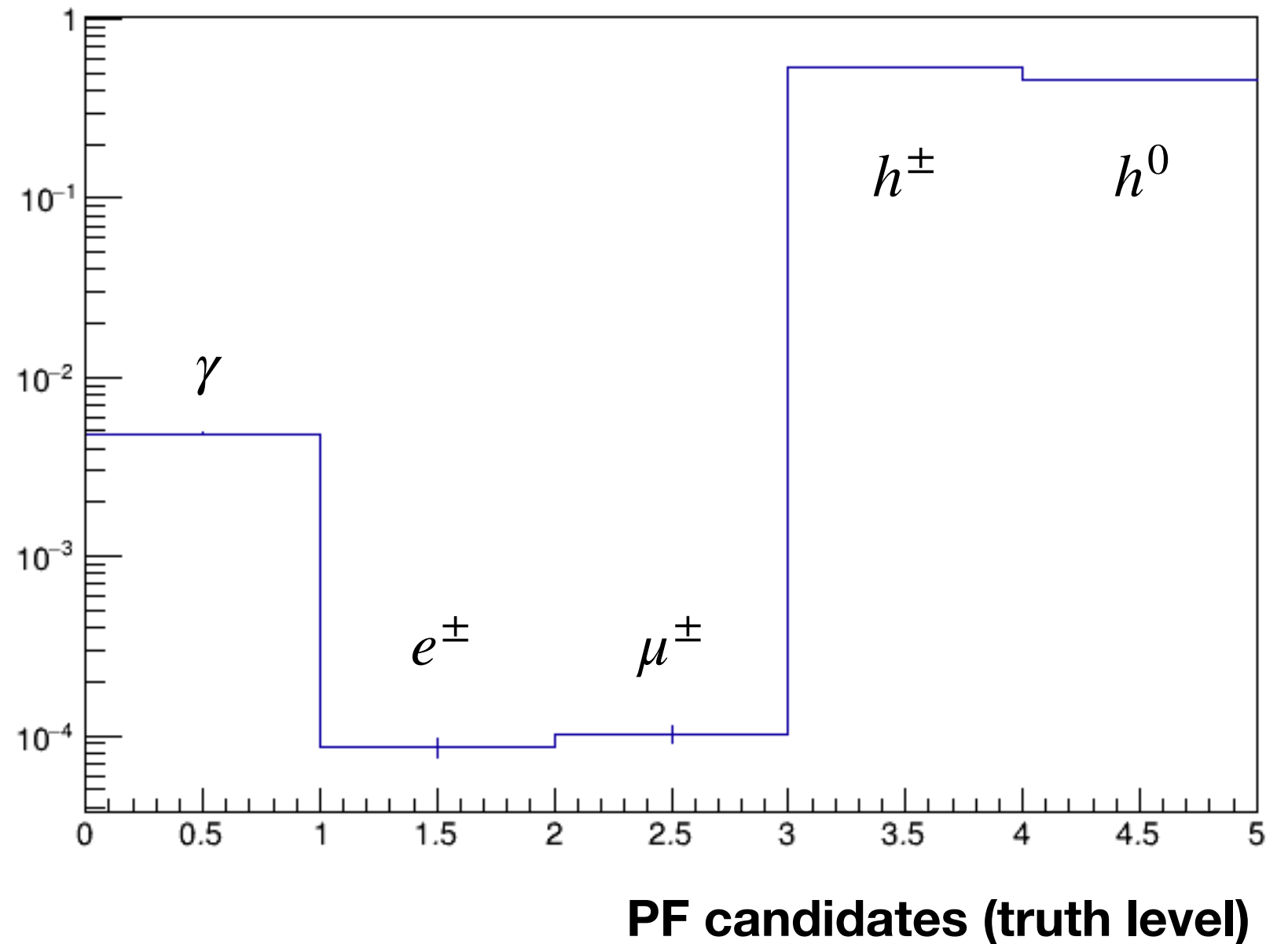
- Mainly utilized at CMS for improvements in jet energy and pointing resolution as compared to calorimeter only jets



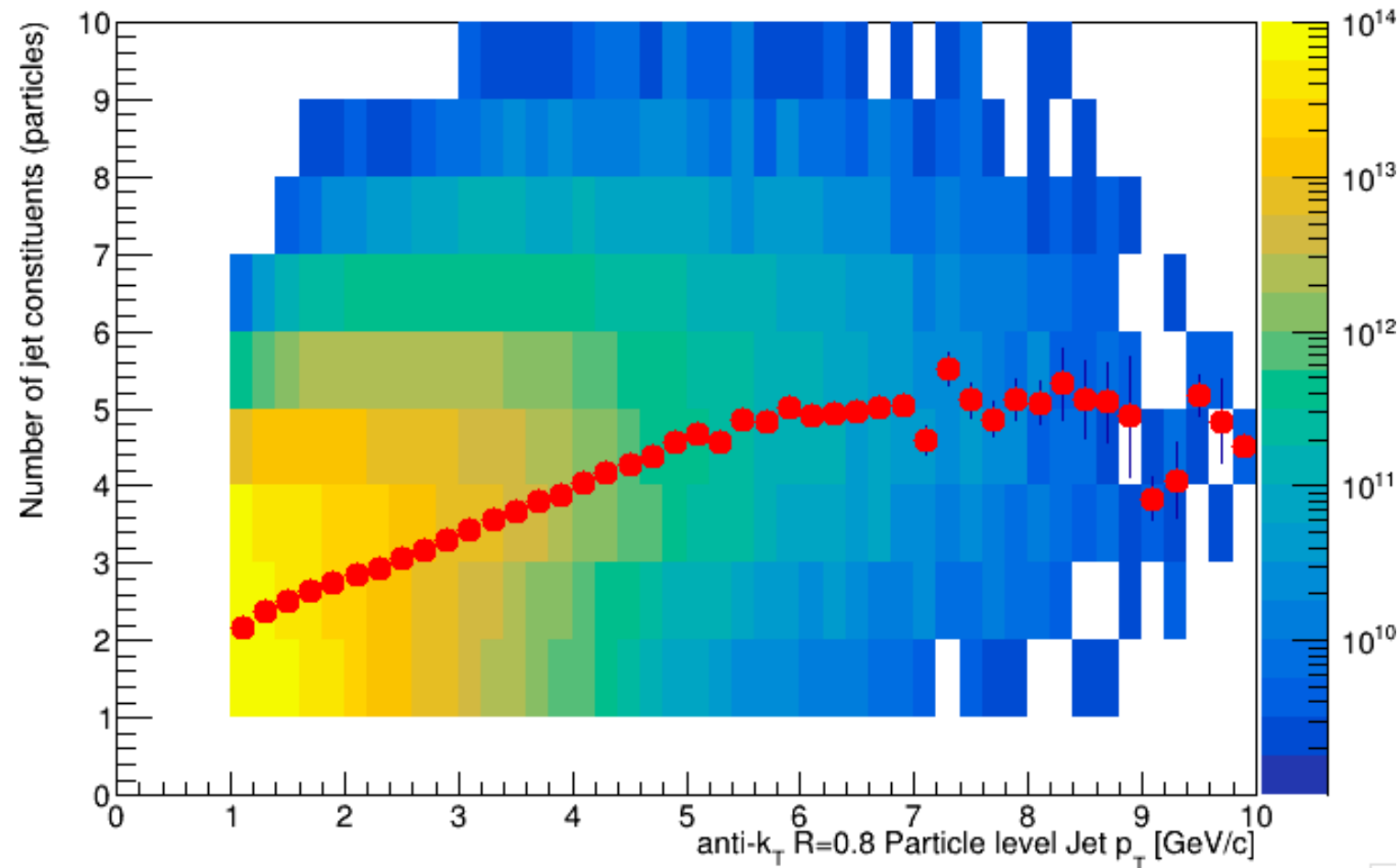
- We can still look forward to reduced jet energy resolution - reduced uncertainties on spectra overall and better correspondence to particle/parton level jet
- Might also be useful for fragmentation function style or angular (sub)structure analysis

# Particles in the forward detectors

- PYTHIA 6 (not STAR tune) minbias events to look at jets in the forward region
- Weak decays are turned off - which is why you see more  $\pi^0$ s compared to  $\gamma$
- Dominated by hadrons with smaller contributions from photons - note these are events with a  $p_{\text{t}} > 1$  GeV



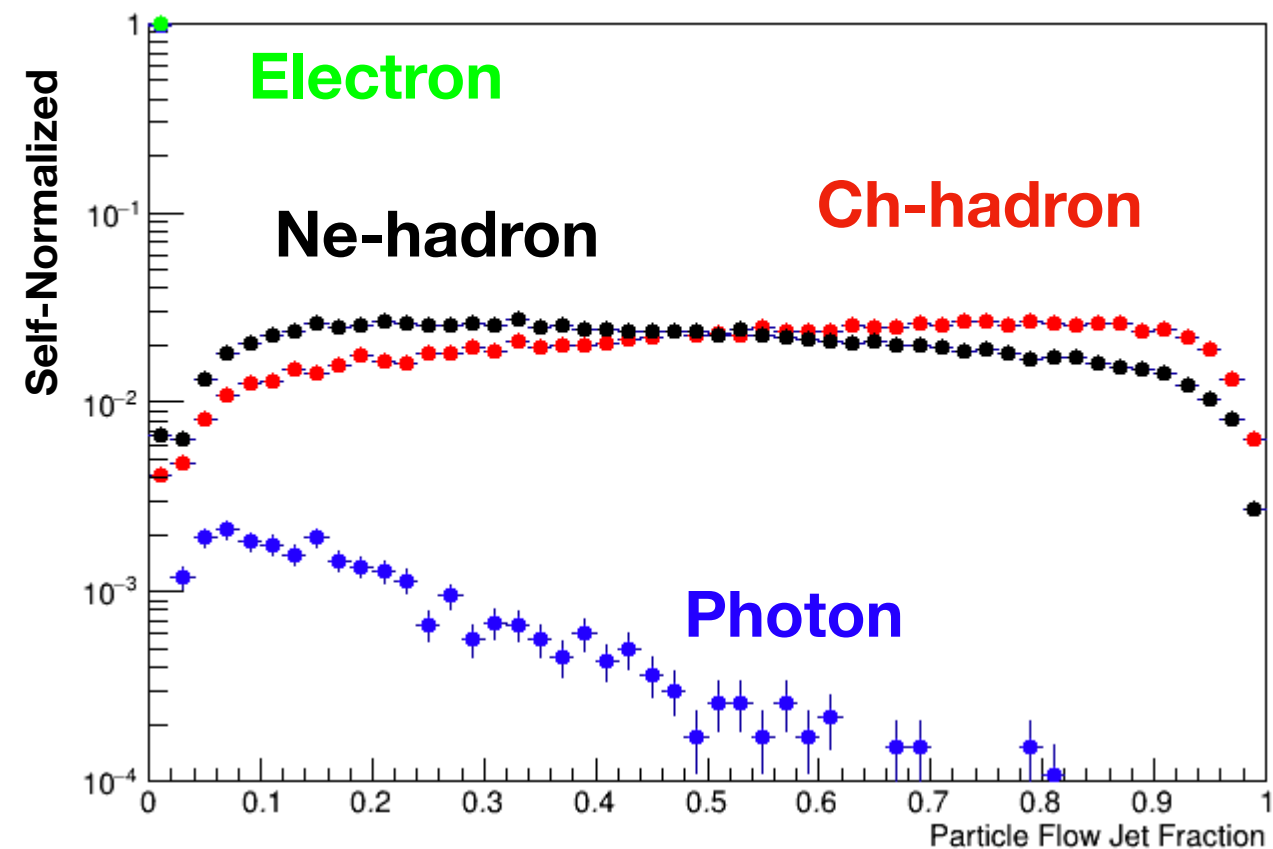




# Forward Jets

- With  $p_T > 3$  GeV, we see roughly 3-5 particles per jet

- PF candidate fractions in jet indicates an overall contribution from ch-hadrons with a small contribution from neutral hadrons
- In this simulation, photons and electrons are sub-percent contributions - can vary the simulation including turning on weak decays to check effect



# Moving forward

- My proposal is to include these at the analysis stage - i.e. in picodsts which can be utilized for analysis

- Utilize the clustering procedure already coded by Akio (code review very soon)
- Start by running full simulations and look at track-cluster matching and running single particle simulations.
- Proposed pico class will have PF candidate 4-momenta and 1 integer to provide the candidate type.

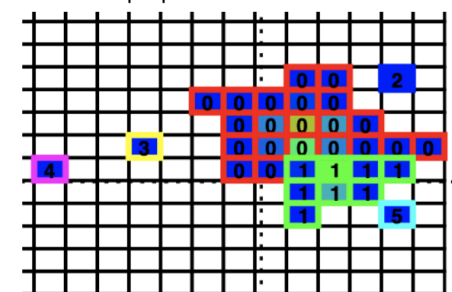
## StFcsClusterMaker

Cluster finder for FCS

<https://www.star.bnl.gov/cgi-bin/protected/viewvc.cgi/cvsroot/offline/upgrades/akio/StRoot/StFcsClusterMaker/>

- Re-write of cluster finder for FMS
- Read StFcsHitCollection
- Sort towers by energy
- Different parameters for Ecal & Hcal
- Looping all towers in descending order
  - If it is neighbor to existing cluster, add to the cluster
  - If not, create new cluster
- Perform cluster moment analysis
- Store resulting clusters in to StFcsClusters
  - Total energy
  - Center position (local coordinate)
  - Set Category, SigmaMax & SigmaMin from moment analysis
  - Pointers to all StFcsHits
  - Pointers to neighbor clusters

Example pi0 event from MC



By StFcsEventDisplayMaker

Color of cell represent energy  
Color of border line (and number) shows which cluster it belongs

*Akio's slides to the software review*

Depending on size of the picodst, this can also be run as an afterburner on the picos/mudsts, assuming we store the clusters...





**HAPPY NEW YEAR**

YEAR OF THE OX